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Colloquium Paper

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Education for industrial ecology

(engineering/interdisciplinary)

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ABSTRACT **The societal issues relevant to the subject of industrial ecology call for the participation of broadly educated engineers who can integrate their technology with the social, political, environmental, and economic aspects of its applications. This increase in the responsibility of traditional engineering to include the end-use, obsolescence, and disposition of technical products signals a new era for engineering education.**

My comments are based on 45 years of personal involvement in public policies on civilian nuclear power and radiation, acid rain, PCBs, electromagnetic fields effects, carbon dioxide and global climate, and other issues that involve the Electric Power Research Institute in public health and safety. I've dealt with almost all phases of such issues, from walking the halls of Congress in 1946 to separate nuclear power from the military to periodic appearances before Congressional Committees and government agencies. One of the barriers was the professional mind-set of my engineering colleagues, and that's what I'm going to talk about today. These remarks are addressed primarily to the industries and agencies that employ the products of the engineering schools and secondarily to the professional engineering societies.

It is useful to place in perspective the magnitude of the problems that we are addressing. During the past half century, the management responsibility of the industrial community for the delivery of goods and services has expanded to include their secondary effects on our social structure (1, 2). I underline the word management, and, as pointed out by Robert Frosch (3), this involves the environment and the ecology in many different ways. This has become a high-priority concern for all industries as well as for the physical waste-producing government agencies. Those of you who follow the Department of Energy's efforts to clean up the military weapons program will realize the magnitude of the problem that a government agency can face (4). It is no longer possible to separate social, political, and economic sciences from the development of industrial technologies.

Thus, the traditional campus separation of the engineering school from the social sciences and humanities school must be bridged more thoroughly to produce the quality of graduates able to contribute constructively to our society's future. The combination of technology and social, economic, environmental, and ecological issues has now become of great public concern and the basis for major social policy, government regulation, industrial development, and international relations. The technological framework of many public issues is a dominant part of their structure and of their solutions. It is evident that in an industrial society, technology frames the options for the way people live. Yet, we do not educate our engineers to contribute effectively in the public search for policy resolution of these societal issues.

We need to substantially enlarge the concept of the engineer's role in our industrial society. The driving force is the recognition by engineers of their accountability for the social outcomes of their work. We have to start with the engineering schools. Engineering schools should lead the way in developing a strong interdisciplinary approach to the issues of the coming decades. We need to establish the teaming of campus resources for a new educational mode. For this reason the subject of environmental science and technology should not be centralized in any one department or any one school of the campus but should be dealt with as an all-university objective. I emphasize this point because the traditional response of every university faced with a fresh responsibility is to establish a new department or a new school that tends to isolate the program.

All schools of engineering now face both a challenge and opportunity in defining their role in such a broad university objective. Traditionally, engineering has concentrated on the conversion of raw materials into goods and services. Engineers have been the deliverer of black boxes but were not responsible for their use. The increased importance of environmental issues has now broadened the responsibility of engineering to include the constructive use and disposition of such products. For example the electric utility industry has learned that it must be concerned with what happens to electricity "beyond the meter." This increase in the responsibility of engineering to include the end-use, obsolescence, and disposition of technical products signals a new era for engineering education.

The consequences of expanding engineering to include a domain "beyond the meter" are profound. Once the goods and services enter the hands of the public, the outcomes of primary, secondary, and tertiary consequences are not completely determinable. Anyone who worked with any of the issues I mentioned earlier would be familiar with such uncertainty. It is evident to many of us who have been involved in such problems that there are now only a few engineers who by virtue of experience and education have an awareness of how such broad problems should be addressed, how they should be communicated to the public, and how a rational basis for policy making should be established. Producing such people represents a major opportunity for the schools of engineering in particular. It is also evident that broadening engineering education to include the total spectrum of activities from the original production of goods and services to their obsolescence and disposal would be good for engineering practice generally. The engineers would learn their proper role in the social system and how to provide improved communication, and it would sensitize them to the broad issues that they will face in the future.

The proposed enlargement of the scope of engineering education also means enlarging the scope of the traditional

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engineering societies and engineering schools' accrediting agencies. These require a bureaucratic transformation that requires the persistent urging and pressure from both industries and government agencies. Anyone who has worked with the structure of engineering schools, engineering societies, and accrediting agencies will realize that they are just as bureaucratic, just as difficult to maneuver as the government agencies that we often complain about, and it takes real pressure to get any change in enlarging the scope of any of these activities. I don't believe that anything less than such urging and pressure from both industries and government agencies will be effective. We need the top-down pressure from the users of the products of the engineering schools—namely, the people in this audience that represent the American industries and government agencies—to create the bottom-up transition in the universities and the engineering societies. Unless this is done, we will have difficulty in getting the engineering profession to play a proper role in the total societal resolution of the public issues that we are discussing at this meeting on industrial ecology.

1. *1990 Integrated Assessment Report: National Acid Precipitation Assessment Program (NAPAP)* (1991) (GPO, Washington).
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3. Frosch, R. A. (1992) *Proc. Natl. Acad. Sci. USA* **89,** 800–803.
4. Nuclear Waste Technical Review Board (1990) *First Report to the U.S. Secretary of Energy* (GPO, Washington).

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